EPA

sciencematters

June 2020

Innovations in Air Quality Monitoring

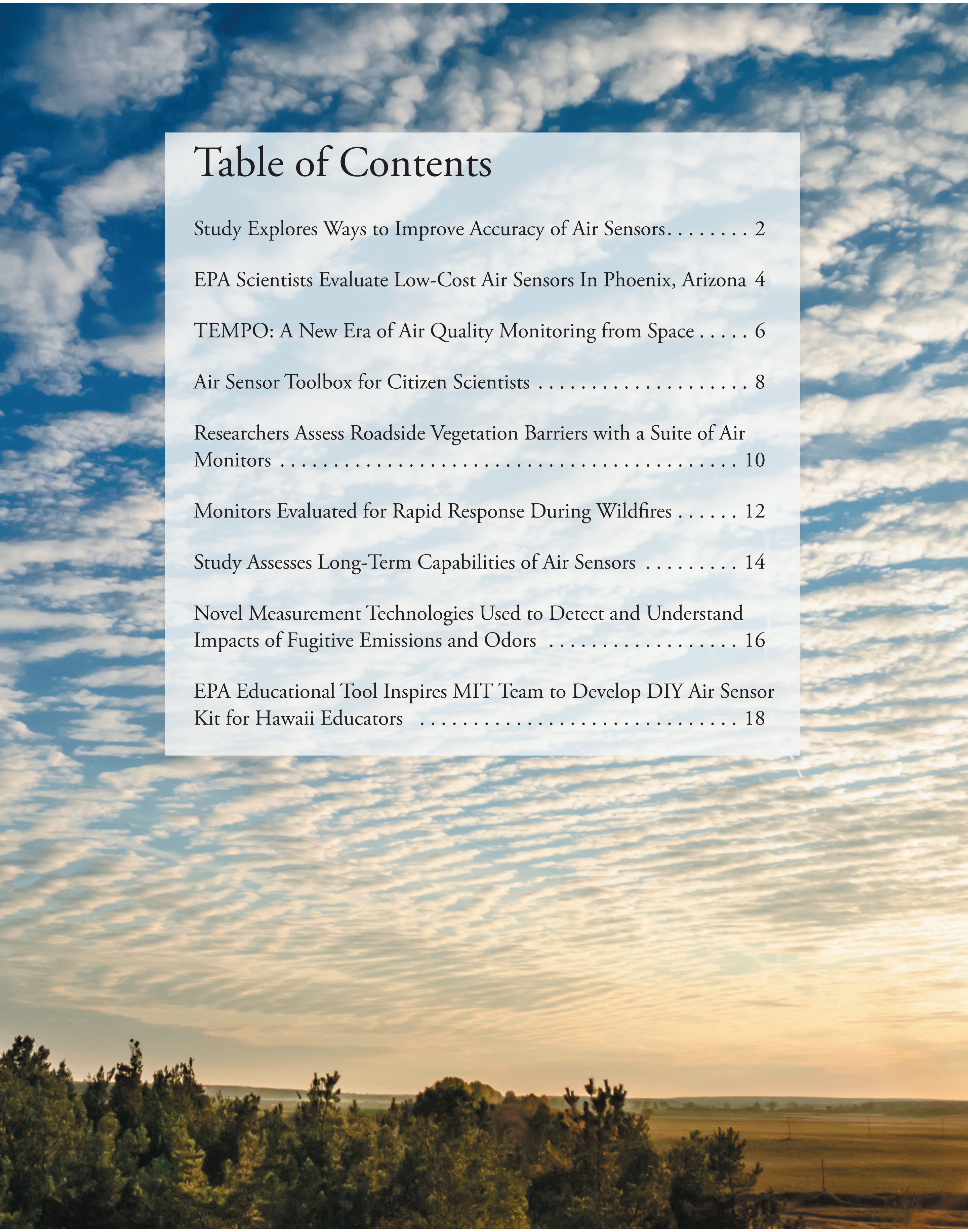


Table of Contents

Study Explores Ways to Improve Accuracy of Air Sensors

Today, air sensors are widely available from a variety of commercial vendors, and their use has become increasingly popular with researchers and the public. They have been used to fill the gaps in understanding of local air quality. Despite the opportunities these air sensors provide to measure air pollutants, questions regarding their operation and performance capabilities remain.

One challenge is that air sensors often overestimate or underestimate pollutant concentrations when compared to regulatory-grade instruments operated in the same location. Sensors can also be affected by factors like environmental conditions such as temperature and relative humidity. EPA scientists aim to account for these factors and improve the accuracy of sensor data by generating mathematical equations to 'correct' the sensor data.

EPA researchers are developing correction equations for several kinds of fine particulate matter (PM2.5) sensors on the market today. In one project, EPA scientists are developing a scientific approach to produce regional and national corrections using sensors made by the company PurpleAir, which are widely used across the U.S. The PurpleAir sensors are being assessed because their use has grown exponentially resulting in an extensive network of publicly reporting sensors worldwide. EPA and more than 30 state, local, and tribal air agency partners have placed these sensors side-by-side with highly robust and accurate regulatory monitors in more than 70 locations throughout the U.S. to evaluate their performance.

"This project is especially exciting because it's leveraging work being done by partner agencies that will lead to the creation of a large dataset of PurpleAir sensors collocated at regulatory air monitoring sites. This kind of data will allow us to better understand these new technologies," says Dr. Andrea Clements, who is part of the sensor research team at EPA.

"Based on this collocation data, we hope to provide a relatively simple equation that will adequately correct PurpleAir data across the U.S. allowing our partner agencies and the U.S. public to have more confidence in this data for a variety of uses," says Dr. Karoline Johnson Barkjohn, EPA ORISE postdoc who is conducting sensor research, along with colleagues.

"This project is especially exciting because it's leveraging work being done by partner agencies that will lead to the creation of a large dataset of PurpleAir sensors collocated at regulatory air monitoring sites."

In addition, EPA is collaborating with the Interagency Wildland Fire Air Quality Response program to investigate how sensors perform during wildland fire smoke events. PurpleAir and other sensors were placed next to highly accurate research monitors near several major wildfires in the western U.S. during the 2018 wildfire season.

"We were able to capture several weeks of very smoky conditions with these sensors and were surprised to find that the same adjustment for PurpleAir sensors developed at low PM2.5 concentrations is still valid during heavy smoke periods," says Dr. Amara Holder, wildfire research project lead.

Disclaimer: Mention of trade names or commercial products does not constitute US EPA endorsement or recommendation for use.

Air sensors operating in close proximity to regulatory-grade or other conventional air quality monitors in Iowa.

EPA Scientists Evaluate Low-Cost Air Sensors In Phoenix, Arizona

Arizona's hot, dry summers, along with dust storms and other harsh conditions, will be the testing ground for low-cost air sensors to determine how well they provide accurate data over time and under different weather conditions.

Though low-cost sensors are not considered suitable for regulatory monitoring, they can provide valuable information about local air quality to state and local stakeholders, which could help identify areas in need of more robust and accurate monitoring and/or efforts to reduce air pollution exposures.

"The accuracy of low-cost sensors can be uncertain. Can you trust what it's telling you? If you're going to put sensors out to tell you what the air quality is, you want to be confident it is giving correct information," says Meredith Kurpius, an air manager from EPA's Region 9 Office.

That's why EPA is working with states, as well as local agencies and tribes to evaluate the ability of certain low-cost sensors to monitor pollutants under different environmental conditions.

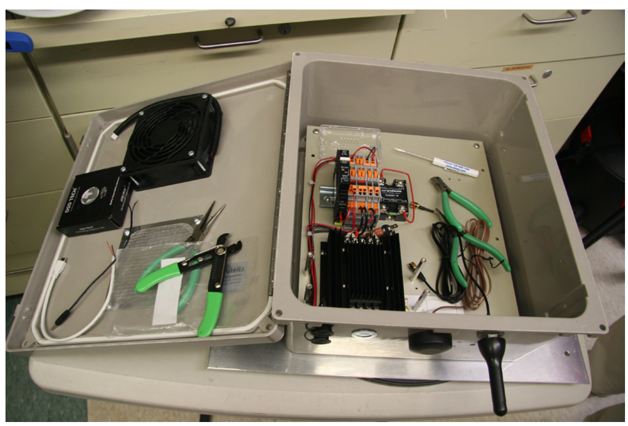
One such project is the "Phoenix as a Testbed for Air Quality Sensors (PTAQS)" study by EPA in collaboration with the Maricopa County Air Quality Department. In June 2019, EPA deployed sensor packages, which include a commercial low-cost air sensor, to measure fine particulate matter (PM2.5), black carbon, and meteorological conditions. The packages will stream minute-by-minute data using EPA's VIPER, a wireless network-based communications system. Researchers will evaluate the sensors over several seasons, which will provide new information on long-term operation and performance.

"This study is all about how low-cost air sensors perform and compare to federal equipment. The hope is that EPA will get some great information on the quality assurance and quality control aspect of these sensors and Maricopa County will get to put sensors in localized areas when they are worried about specific sources of PM2.5," says Sue Kimbrough, lead EPA researcher of the PTAQS study.

EPA researchers are placing sensors throughout Phoenix in areas where biomass burning is more prevalent in the winter to assist the county with its Fireplace Retrofit Program. Fine particulate matter can come from many sources including motor vehicles, power plants and wood burning. To observe the output of PM2.5 from woodburning fireplaces specifically, researchers are measuring black carbon in addition to PM2.5, which is a good marker for biomass burning. The Fireplace Retrofit Program encourages homeowners in areas shown to have the highest PM2.5 concentrations during wood burning season to put in more efficient systems that reduce air pollution, such as switching to a natural gas log set or installing an air pollution reduction device.

Tina Wesoloskie from Maricopa County Air Quality Department says, "This program is a good chance to link fireplaces with poor air quality and air quality-induced health effects in the mind of residents."

The research contributes to EPA's expanding activities to partner with state, tribal, and local air agencies to deploy sensors to collect information relevant to community needs. At the end of the study, EPA will share results with all collaborators.



A sensor package which includes a commercial low-cost air sensor, to measure fine particulate matter (PM2.5), black carbon, and meteorological conditions.

TEMPO: A New Era of Air Quality Monitoring from Space

Understanding what's in our air, including pollution and its sources, is important to safeguard public health and the environment. Satellites have become essential tools for tracking weather events like thunderstorms, tornadoes, and hurricanes, as well as for improving daily weather forecasts. Now, satellites are increasingly being used to monitor air quality and the movement of pollution in the air we breathe.

EPA scientists are currently collaborating with the National Aeronautics and Space Administration (NASA), the Smithsonian Astrophysical Observatory (SAO) and the National Oceanic and Atmospheric Administration (NOAA) on a project that will use satellites to examine air quality across North America. Launching in 2022, the Tropospheric Emissions: Monitoring of Pollution (TEMPO) satellite instrument will monitor air quality during the daylight hours in geostationary orbit, at a vantage point about 22,000 miles above Earth's equator.

“Geostationary satellites orbit the Earth's equatorial plane at a speed matching the Earth's rotation,” explains EPA senior research scientist, Jim Szykman. “This allows the instrument to stare at the same position on the earth's surface and monitor changes over one location throughout the day. TEMPO also has the capability to measure air quality during the daylight hours across North America,” he adds. “This will enable us to evaluate how the pollutants being measured are changing over different time periods through the day and evaluate different processes that influence the level of pollutants.”

Measuring Pollutants From Space

Weather satellites used by NOAA can easily track the evolution of aerosols released into the atmosphere from dust-storms and large wildfires, but aerosols can also be formed by gaseous pollutants such as nitrogen dioxide, sulfur dioxide and formaldhyde, which react to form particles and ozone. TEMPO will be able to observe these gasses at much higher temporal and spatial resolution than weather satellites.

TEMPO monitoring capabilities have the potential to revolutionize air quality forecasts.

These measurements will allow researchers to observe pollutant emissions and see how pollution episodes evolve over hours, days, and weeks, interacting with weather patterns as they move across the landscape.

“The interaction between weather and the level of pollutants in the atmosphere controls the air quality we experience throughout the day, impacting the amounts of ozone and particulates that are present in specific areas,” Szykman says. “Sunshine, rain, higher temperatures, wind speed, air turbulence, and mixing depths all affect pollutant concentrations.”

Preparing for the TEMPO Mission

TEMPO is part of NASA's Earth Venture Instrument program and will join similar satellites, including South Korea's Geostationary Environment Monitoring Spectrometer (launched in February 2020) and the European Space Agency's Sentinel-4 (launching in 2023) to form a global air-quality satellite constellation. Together,

A ground-based Pandora spectrometer for satellite validation on the New Jersey Department of Environmental Protection air quality monitoring site at Rutgers University in New Brunswick, NJ.

these satellites will provide coordinated observations of air pollution across all continents in the northern hemisphere.

As members of the TEMPO science team, EPA scientists are collaborating with NASA and other state and local agencies to build an air quality validation network of ground-based spectrometers, called Pandoras, at air quality sites across the country.

EPA research is also helping to develop applications for TEMPO data to improve the underlying science, which informs air quality management.

Anticipated benefits and applications of TEMPO data include:

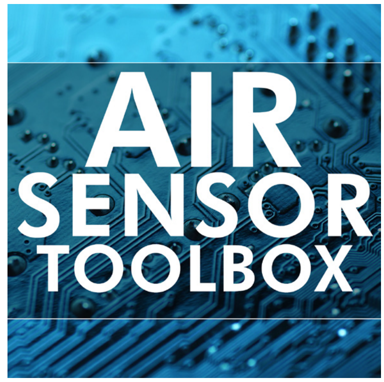
- Improved understanding of pollution sources and how the emissions for sources vary throughout the day.
- Better monitoring of smoke from fires, including how the emissions from fire impact the formation of ozone and particulate matter.
- Improved air quality warnings and alerts.
- Better detection of how stratospheric ozone may impact surface ozone values, particularly in the mountainous western U.S.
- Improved understanding of lightning generated nitrogen oxides emissions.

Kelly Chance, TEMPO'S Principal Investigator, looks forward to continuing a close collaboration with EPA after TEMPO's launch.

"EPA is a critical partner in TEMPO, as they are our national agency for the measurement and control of environmental health factors," Chance says. "TEMPO measurements will be directly used by EPA for air quality and health applications, provision of customizable publicly-available data, pollution forecasts and inventories, regional and local transport of pollutants, and air quality responses to changes in emissions. The EPA TEMPO partnership will significantly improve the North American environment and the health of humans, animals and crops."

Air Sensor Toolbox Website

The web-based Air Sensor Toolbox is a primary source of information on EPA's air sensor-related activities and research. Check out the newly updated Toolbox, which includes new content and improved navigation to topics of interest.



- Learn about sensor performance, evaluation and use.
- Understand what your sensor data readings mean.
- Find out what is being done to establish performance targets for sensors.
- Keep informed about EPA's air sensor research projects.
- Access additional resources, including frequently asked questions.

Visit the Air Sensor Toolbox: www.epa.gov/air-sensor-toolbox

Take a Look Inside the Air Sensor Toolbox

These and other resources are available online

Educational Videos on Air Sensors

EPA has developed educational videos on air sensors in English and Spanish that can be used to learn how the Agency collects and uses air quality data, how air quality health risks are communicated and how to interpret data collected using air sensors.

Air Sensor Guidebook

The Air Sensor Guidebook can help with your air monitoring project. Learn about air pollutants, ways to use air sensors, what features to look for in a sensor, how to evaluate the performance of a sensor and how to collect data.

Sensor Collocation Guide and Macro Analysis Tool

EPA's sensor collocation guide and Macro-Analysis Tool can be used to evaluate the performance of an air sensor by comparing it to a regulatory monitor and interpret the data that is collected. The resource is suitable for citizen scientists, community groups and experts alike.

RETIGO: Data Mapping Tool

Real Time Geospatial Data Viewer (RETIGO) is a free, web-based tool developed by EPA that can be used to explore any kind of environmental data in a neighborhood, community, or other location. The tool can be used to produce graphics to show how pollution varies by location and during the time of day or how pollution levels change with wind speed and direction, for example.

Air Sensor Performance Evaluations

You want to purchase an air sensor to take some air quality measurements. Which device should you select? While EPA cannot make recommendations, researchers have evaluated the performance of some commercial sensors and made the results available on the Toolbox.

Air Sensor Loan Programs

EPA has established air sensor loan programs through various collaborations with community groups, schools, libraries, and others to enable the public to learn about air quality in their communities. These programs are provided to bring new air sensor technology advances to the public for educational purposes. Sensors available through these loan programs are not intended for regulatory use.

Educational Resources

Air sensor technologies provide many opportunities for educational enrichment. Educational activities and curriculum developed by EPA and with collaborators are available for use by the public. These resources are ideal for use in the classroom, community workshops, or other educational settings.

Researchers Assess Roadside Vegetation Barriers with a Suite of Air Monitors

New and innovative air monitoring approaches are helping researchers learn more about solid and vegetation barriers and their ability to reduce exposures to harmful roadside air pollution. The work could benefit the health of millions of Americans who live, work, and go to school near major highways or other transportation facilities such as an airport or railyard.

Two pilot studies using vegetation barriers near roadways are under way with community partners—one at an elementary school in Oakland, California, and the other at a residential park in Detroit, Michigan. At both sites, community partners planted vegetation barriers and are assisting with monitoring while researchers measure air quality and weather patterns before and after planting the barriers to evaluate their ability to reduce and filter out air pollution.

A variety of air monitoring tools are being used to assess air pollution in and around the school and park including stationary and mobile research-grade monitors and air sensors. Portable sensors, which can be handheld or put in backpacks, will be used by community members while walking or biking. An EPA electric vehicle filled with sensors and regulatory monitors is providing additional air quality data, as well. Project partners are also using kid-friendly air quality monitors like the "birdhouse" developed by the scientists who also developed a science curriculum to teach elementary school students about air quality.

Richard Baldauf, an EPA scientist and one of the project leads, says using different types of monitors strengthens the study. "Since all air monitoring techniques have different strengths and limitations, we use a combination of methods to effectively and efficiently gather the information needed," he explains. "Combining methods also gives us a clearer understanding of the accuracy and representativeness of the measurements we collect."

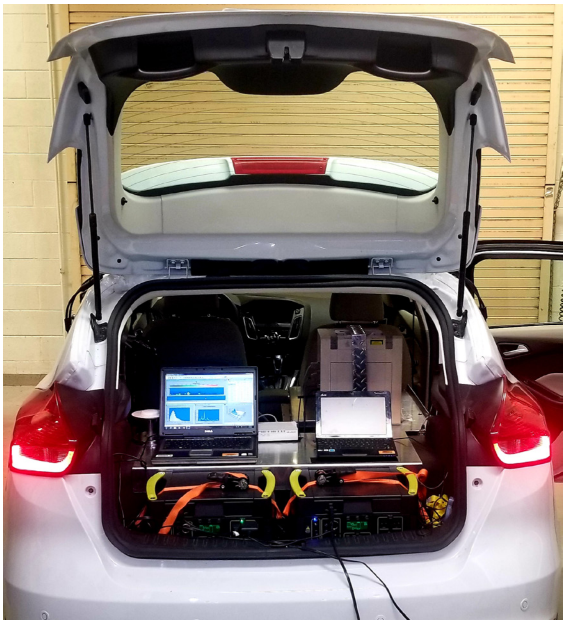
Using the monitor data, the researchers can create and evaluate models of how pollutants travel from roads into communities. This will allow them to see whether different types of vegetation barriers block pollutants by changing the airflow near roads or filtering pollutants from the air.

The sites in Oakland and Detroit will help researchers determine which types of vegetation barriers—such as bushes, trees, or a combination—may be most effective. The studies will take another two to three years to complete but results from similar EPA field studies suggest a combination of bushes and trees more effectively stops pollutants than no vegetation or vegetation with gaps.

In previous studies, the thick, tall vegetation barriers reduced downwind particle pollution by as much as 50 percent and other pollutants by 20-30 percent. These results show roadside vegetation is a promising strategy for communities to improve air quality and public health when designed and maintained properly.

The research is bringing together high technology and green barriers from mother nature together to find new ways to protect people from air pollution.

This work is part of a larger research effort to understand air pollution exposures in near road environments, in response to the need to support air quality management programs within EPA's Office of Air and Radiation.



Above: An EPA vehicle equipped with mobile air quality monitoring technology.

Right: An EPA air monitor called the birdhouse, built for use by students.

Advancing Measurement and Monitoring Technology for Wildland Fire Smoke

Monitors Evaluated for Rapid Response During Wildfires

The Mobile Ambient Smoke Investigation Capability (MASIC) study, launched May 2019, is collecting air measurements from both EPA designated reference and non-regulatory instruments to determine their performance capabilities during impacts from wildfires. Researchers are using mobile laboratories to measure emissions near wildfires as they occur. One mobile laboratory is equipped with primarily state of-the-art research grade instruments and regulatory air quality monitors and the other with portable non-regulatory instruments.

In addition, three comprehensive fixed sites have been set up in wildfire-prone areas in Reno, Nevada, Boise, Idaho, and Missoula, Montana. Researchers are collecting air monitoring data and comparing the performance of regulatory and portable non-regulatory instruments at these sites and mobile laboratories during wildfire smoke events.

The studies will help researchers interpret data from regulatory monitoring and supplemental networks during wildfires and also provide information on the efficacy of using rapidly deployable devices for fire incident response. The research is expected to continue through 2022.

Air Sensors Mobilized to Measure Indoor Air Quality

EPA researchers are using state-of-the-art air sensor technology in a study to learn more about how air cleaning and ventilation practices impact indoor air quality during wildfire events. The main pollutant being measured is fine particulate matter or PM2.5, which is found in smoke from wildfires and can cause a variety of health effects. The study is being conducted in partnership with the Missoula City and County Health Dept in Montana, and Hoopa Valley Tribe in California.

The researchers aim to better understand and characterize how wildfire smoke and other sources of air pollution impact indoor and outdoor air quality and what may be good strategies to reduce indoor concentrations.

Small PM2.5 sensors are being placed indoors and outdoors of a variety of different types of commercial and public facilities in cooperation with the owners. In addition, a small sampling package will be added to a research vehicle to map outdoor smoke concentrations and to understand how the smoke levels may vary throughout the surrounding area.

A complementary laboratory study at EPA in Research Triangle Park, North Carolina, will evaluate the effectiveness of portable air cleaners and air filtration systems in removing PM2.5 under simulated pollution levels found during wildfires.

EPA scientist Amara Holder with air cleaner in a laboratory testing chamber.

Kolibri System Takes to the Sky to Measure Emissions

Kolibri, a new sensor system for mobile and aerial emission sampling, was developed by EPA researchers for open area pollutant sources, such as prescribed burns. The lightweight air sampler weighs up to eight pounds and can be used on an unmanned aerial system (UAS, or drone) to measure emissions.

EPA has placed its Kolibri system on UASs owned and operated by other agencies to provide data for the U.S. Department of Defense and others. The Kolibri is controlled by a microcontroller, which can record and transfer data in real time through a radio module. The sampler also can measure and sample a broad variety of compounds. Due to its dynamic sensor response, the Kolibri can be applied to various challenging open area scenarios such as fires, lagoons, flares, and landfills as well as forest and agricultural burns.

The novel air instrument is being used in multiple applications in the field to characterize the chemical and biological composition of smoke emissions from open area burns, including wildland fires. In 2020, researchers plan to use Kolibri to study emissions during wildfire-like prescribed burns with the U.S. Forest Service; emissions of oil burns on water with the U.S. Department of Interior; and emissions with open detonation demilitarization operations with the Department of Defense.

Top photo: The Kolibri air sensor, a lightweight sampler developed by EPA researchers, samples chemical, particle, and biological pollutants as it is carried through smoke in an unmanned aircraft.

Study Assesses Long-Term Capabilities of Air Sensors

New air sensor technology is offering ways for individuals, communities, and researchers to learn more about air quality, but many questions remain about sensor performance and reliability over time and under different climate conditions.

Commercial air sensors can be purchased for a few hundred to a few thousand dollars, depending on the measurements included, and offer user-friendly features that require little or no technical knowledge to start collecting data. These advances have resulted in air sensor systems being used by a wide variety of organizations from community groups to air quality professionals.

Despite the opportunities low-cost sensors provide to better understand local air quality conditions, there are many uncertainties about the technology's operating and performance capabilities. Studies by EPA and others have shown that results from air sensors do not always compare well to high-quality regulatory monitors, which are used to implement the nation's air quality standards. These more expensive reference monitors have undergone rigorous independent scientific evaluation and testing.

EPA is filling the knowledge gap of air sensor performance by evaluating commercial sensors, working with developers, testing sensors in the lab and collaborating with partners to test sensors in communities. Previous studies primarily have been short-term, lasting weeks or a few months. Researchers recognize the need for long-term evaluations in a variety of seasons and conditions to gain better insight into the performance and reliability of sensors over time and under different conditions.

In July 2019, EPA began the Long-Term Performance Project to tackle questions about long-term use of air sensors, and their performance and capabilities. Researchers will evaluate six models of commercial air sensors, placing them in seven locations with diverse climates and air quality conditions across the country, including EPA's test site in Durham, North Carolina. The other locations are Wilmington, Delaware; Phoenix, Arizona; Atlanta, Georgia; Denver, Colorado; Edmond, Oklahoma; and Milwaukee, Wisconsin.

"Most sensor testing has been done in a few locations, but people want to measure air quality everywhere," explains Dr. Andrea Clements, the technical lead on the project. "If we want to use them with confidence in the results, they will have to be tested in more locations and under different conditions," she says.

The test sites all have reference monitors for comparison

purposes and offer a wide variety of airshed conditions that may impact sensor accuracy and performance. Air quality is not the same across the country and is influenced by the types of air pollutants common in an area, particle size and composition, weather conditions such as high and low humidity, temperature, or rain, and geographic characteristics.

The devices to be tested measure one or more pollutants (e.g., particulate matter, ozone, nitrogen dioxide) and meteorological conditions. The research project is the largest of its kind by EPA to compare different sensors at a variety of locations in the U.S., with the goal to provide independent scientific information about long-term use of sensors.

Research questions include:

• How accurate are the sensors when compared to reference monitors?

• How well do they operate under different climates, including high and low humidity or temperatures and extreme weather events such as wildfires or dust storms?

• What is the life expectancy of the sensors and what observations indicate sensor failure or malfunctioning?

• What additional guidance can be developed to improve the reliability of data and performance of sensors during use?

While only six types of devices are being tested, the information gained can be applied broadly since similar sensor components are used widely by the air sensor industry. It is anticipated that data collected will be helpful to other manufacturers as well as those whose products are being evaluated.

An extension of the Long-Term Performance Project is an assessment of the PurpleAir sensor with participation from state and local agencies that are currently testing the device across the United States. (See article on page 2).

Photo left: Researchers work on one of the sensors prior to the field study.

Deliberating Air Sensor Performance Targets

There is growing recognition of the need for performance targets for air sensors to improve the reliability of the data they produce. While many commercial products are now available to anyone who wants to measure air quality, there is no independent or government-based program they can turn to for guidance on which sensors produce accurate measurements.

EPA has conducted two workshops to obtain perspectives from various stakeholders (including air pollution regulatory agencies, academic researchers, manufacturers, developers, and others) on the need for performance targets for air sensors for non-regulatory supplemental and informational monitoring applications.

An initial workshop in 2018 focused on fine particulate matter (PM2.5) and ozone (O3), and the findings have been summarized in a journal article (https://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryId=344961&Lab=NERL). A second workshop in 2019 addressed particulate matter with aerodynamic diameters of 10 microns or less (PM10), nitrogen dioxide (NO2), sulfur dioxide (SO2), and carbon monoxide (CO). EPA developed a journal article (currently under review) summarizing the second workshop.

EPA is developing interim air sensor performance targets and associated testing protocols for PM2.5 and O3 that are anticipated to be released as separate reports in Fall 2020.

Visit the air sensor toolbox for the publications: www.epa.gov/air-sensor-toolbox

Novel Measurement Technologies Used to Detect and Understand Impacts of Fugitive Emissions and Odors

EPA's Next Generation Emissions Measurement (NGEM) research team is working collaboratively with industry, state and local regulators, communities, and technology companies to develop new and innovative technical approaches for detecting and fixing fugitive industrial volatile organic compound (VOC) emissions.

Fugitive emissions that escape through leaks, industrial processes, and other means are currently regulated by federal, and in some cases, state rules that require manual monitoring of industrial equipment, followed by equipment repairs to address the emissions. If these unanticipated emissions can be detected and fixed in a timely manner, there are many benefits including: safer working environments; cost savings through reduced product loss; and reduced air pollution and improved public health protection.

Some of these technologies are described below.

Fenceline Monitoring with a VOC SPod

At a project in Louisville, Kentucky, researchers deployed their prototype VOC measurement technologies beginning in 2017 in the Rubbertown industrial district where poor air quality and odor issues have been raised by local neighborhoods. The system, called the SPod, is a portable, lower-cost sensor system that measures total VOCs and can be placed along the perimeter of a facility to detect leaks that can result in plumes of pollutants moving into nearby communities. The SPod design is open source and has since been commercialized with instruments now available on the market for fenceline monitoring.

Technical Contact: Eben Thoma, thoma.eben@epa.gov

Odor VOC Emissions Tracker (oVET)

The Rubbertown area industrial district in Louisville, Kentucky, like many others, has struggled with odor issues due to fugitive VOC emissions from industrial facilities and other facilities in the area. Fugitive odor emissions are particularly challenging to detect and identify because they are highly variable and complex in nature. To address odor complaints, researchers developed a VOC sensor system called the Odor VOC Emissions Tracker (oVET).

The oVET incorporates three complementary innovative measurement approaches: 1) a customized portable gas chromatograph (GC) for continuous odorous VOC monitoring, 2) automated canister sampling to aid in source identification, and 3) an SPod for real-time VOC emissions detection. The combination of these technologies can detect fugitive VOC emissions in real-time and quantify specific odorous air toxic VOCs.

The oVET project has been piloted in the Rubbertown area in partnership with the Louisville Metro Air Pollution Control District (LMAPCD). The pilot concluded in January 2020 and data collected will aid Louisville and the state in identifying odiferous air toxic emission sources contributing to odor issues in Rubbertown.

The VET system concept can be customized to address any number of industrial emission concerns by replacing the portable GC with a different VOC monitoring instrument or sensor to focus on assessing emissions of a particular group of VOCs or hazardous air pollutants (HAPs) of interest. As the VET platform matures and various elements are developed and tested, the release of open-source designs are envisioned.

Technical Contact: Ingrid George, george.ingrid@epa.gov

Odor Explore App

Odors come from many different sources, can negatively impact communities, and are extremely challenging to understand because they can be persistent and unpredictable. Researchers are leading the development of a mobile phone app called "Odor Explore" that enables the public to report odors in their community and view reports submitted by others.

This effort includes deploying remotely operated canister sampler (ROCS) systems (see description below) placed in key locations around a community that can be triggered to instantly gather air samples remotely when reports from the odor app indicate an odor problem. These measurements may be able to provide a chemical snapshot of what is in the air that can then be linked to specific sources.

The app will help engage and empower communities and provide valuable information that can be used by EPA, states, tribes, local governments, and industries to develop air pollution and odor control mitigation strategies. The Odor Explore app is under development and prototype versions for iOS and Android are anticipated to be completed for pilot testing in 2020. In partnership with the Louisville Metro Air Pollution Control District, the app will be tested in different neighborhoods around Louisville that are impacted by odors including the Rubbertown industrial area where NGEM technology has been deployed in earlier demonstration projects.

Technical Contact: Rachelle Duvall, duvall.rachelle@epa.gov

Remotely Operated Canister Sampler (ROCS)

The NGEM research team is building a new VOC canister sampling system that can be remotely triggered by text message called the Remotely Operated Canister Sampler (ROCS). The sampling system will first be piloted in Carlsbad, New Mexico, as part of a regional research project with the New Mexico Environment Department and the National Park Service. The goal of this project is to use the ROCS to understand how ozone precursors vary spatially and under different meteorological conditions and identify emission sources in New Mexico.

The ROCS will also be deployed in the Louisville, KY area as part of the Odor Explore App project (see description above) to understand VOC emissions that may contribute to odor problems.

Technical Contact: Ingrid George, george.ingrid@epa.gov

Sensor Network Leak Detection System

An EPA Cooperative Research and Development Agreement (CRADA) with Flint Hills Resources (FHR), a refinery operator, and Molex, a connector and sensor company, was initiated in 2017 to develop, test, and deploy new remote sensing approaches for fugitive leak detection inside industrial facilities. This collaborative research project specifically investigates the use of an in-facility sensor network as an alternative to the currently required manual leak detection procedures, which are expensive and take time to perform. For a typical refinery, annual costs can exceed millions of dollars. The team assembled for the project included industry experts, sensor designers, scientists, and engineers.

A pilot project in two refinery process units in Texas involved successful demonstration of a network of over 50 leak detection sensor nodes. The initial phase of the CRADA is almost complete and a report summarizing the engineering development and testing is being prepared.

Technical Contact: Eben Thoma, thoma.eben@epa.gov

EPA Educational Tool Inspires MIT Team to Develop DIY Air Sensor Kit for Hawaii Educators

Educators at Massachusetts Institute of Technology (MIT) have built on an EPA educational tool to create a new version of a particle meter to help teachers in Hawaii teach students about air quality and engineering. The MIT sensor design encourages hands-on learning at a time when more U.S. schools are embracing "makerspaces," areas where students can explore and create using materials from art supplies to electronics.

Dr. Kathleen Vandiver, the outreach director at MIT's Center for Environmental Health Sciences, said she and the Edgerton Center team drew inspiration for an engineering project from EPA's "Build your own particle sensor" activity, designed to teach middle school students about air quality. In the MIT activity, participants in teams of two assemble the electrical components and upload a simple code to build a hand-held particulate matter (PM) meter. The exercise familiarizes teachers and students with how sensors can be built to detect particles in the air and produce signals that can be read.

Dr. Rachelle Duvall, an EPA researcher and active participant in EPA's STEM outreach program, said of the project, "It is exciting to see how educational resources developed by EPA are creatively used and adapted for other projects. This definitely shows how science matters!

The sensor kit and its assembly instructions grew out of a larger, EPA-funded STAR grant project led by MIT and local community partner The Kohala Center, an independent community-based research center on Hawaii's Big Island, to monitor harmful pollutants emitting from Hawaii's Kilauea volcano. The MIT project team deployed a network of research air sensors on school grounds and health clinics across the Big Island to provide communities with their own local and real-time measurements for sulfur dioxide and particulate matter pollution, which combine to form volcanic smog, or "vog."

Volcanic smog has negative impacts on human health, such as the potential to aggravate pre-existing respiratory ailments. It can also harm plants and agriculture. When the Kilauea volcano erupted in May 2018, the Hawaii Vog Sensor Network Team at MIT rushed to deploy additional sensors onto the network to provide real-time local health data to the communities living nearby. In August 2018, when the Kilauea lava flow slowed and the students were back in school, the recorded data from among the different schools' air sensor nodes was shared across the island.

A full day teacher workshop in September 2018 was one of these data sharing events. To acquaint teachers with air sensor technology, Vandiver showed them how to assemble

handheld air sensors. The workshop not only emphasized teaching STEM concepts, but also connected the lessons to real-world, local environmental issues of vog and Hawaiian cultural values led by the Kohala Center's staff.

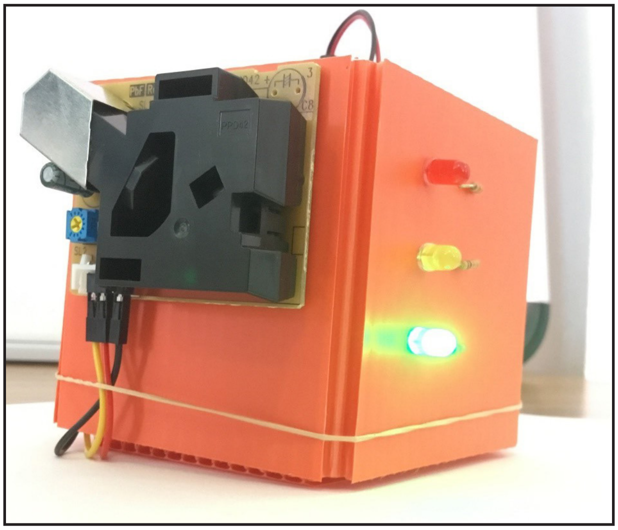
Vandiver also shared lessons she designed to teach basic chemistry using LEGO™ bricks to represent atoms. With the lesson plans available for download here, all the EPA's criteria air pollutants can be easily modeled, as well as many key concepts needed to explain climate change, such as the chemical processes in combustion, ocean acidification, and photosynthesis.

Following the success of the workshop, MIT donated six of the MIT Edgerton Center's Molecule Sets for classrooms to the Kohala Center to loan out to trained teachers on the island, which Vandiver said are "very popular" with teachers and students. Vandiver points out, "The MIT Edgerton Center Molecule Set teaches abstract concepts in concrete ways©."

Photo left: At a workshop in Waimea, Hawaii, high school teachers Heather O'Connell (left) and Una Burns (right) learn how to assemble the particle sensors with the MIT team's instructions.

The instructions for building the MIT Edgerton Center's particle sensor kits are here: http://edgerton.mit.edu/k-12/teacher-resources/k-12-curriculum/stem-projects/arduino-particle-meter and can be reposted with attribution.

Find the Creative Commons license here: http://edgerton.mit.edu/node/103



A fully assembled particle sensor. The handheld device introduces students to data collection by allowing them to measure particulates in the air.

June 2020

United States Environmental Protection Agency
Office of Research and Development (8101R)
Washington, DC 20460